Nationaal Lucht- en Ruimtevaartlaboratorium

National Aerospace Laboratory NLR

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Feasibility and prototyping for the future aurveillance data processing and distribution system

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Feasibility and prototyping for the future surveillance data processing and distribution system

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Summary

This paper contains a summary of the presentation on the ARTAS2 tracker feasibility study at the first Eurocontrol ADS workshop.
It provides an overview of the architecture of the ARTAS2 system.
This architecture is designed to smoothly integrate data from both ground based and airborne data sources.
Secondly, the paper contains initial results of the ARTAS2 tracker prototype. These results show that there is a clear performance gain when using aircraft-derived data with respect to a radar-only surveillance environment.

Contents

(14 pages in total)

1 Introduction

This paper describes the activities that are performed to assess the feasibility of a Surveillance Data Processing and Distribution (SDPD) system that integrates the ADS and Mode-S technologies with the existing radar surveillance in such a way that it benefits from the strong points of each technology.
The contents of this paper are as follows: section 2 describes the requirements for such a SDPD system. Section 3 introduces a solution, based on and evolving from the existing ARTAS SDPD. Section 4 describes the results of integration of ADS and Mode-S and presents some performance results. Section 5 describes the ADS Quality of Service study, which is aimed at deriving realistic requirements for the future SDPD. Section 6, finally, contains a summary.

2 Major Requirements for the Future SDPD

2.1 Functional Requirements

The environment in which the future EATCHIP SDPD system will operate is evolving. Specifically, the future SDPD will be required to operate in an environment with

- A complex, evolving, heterogeneous set of Surveillance Data Providers, including the new types of Data Sources, such as the SSR Mode-S, ADS-B and ADS-C.
- An increased number of Surveillance Data Users, with requirements for an increased number of Surveillance data items, according to their specific needs.

The ECAC Surveillance Strategy (ref. [1]) and EATMS (ref. [2]) foresee a heterogeneous set of Surveillance Data Sources, co-existing across ECAC. Classical Data Sources (i.e. Primary and Secondary Radars) and the new Data Sources (i.e. SSR Mode-S, ADS-B and -C) will be integrated into the future surveillance environment.

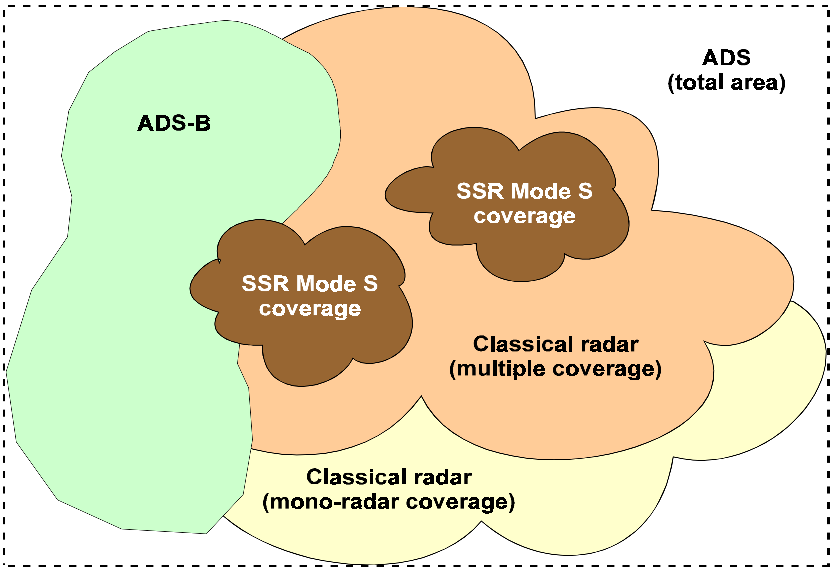


Fig. 1 Example of heterogeneous coverage of different basic Surveillance Data Providers

The additional Surveillance Data Sources result in a heterogeneous environment of Surveillance Data Providers over Europe and its bordering oceanic areas, which are likely to be as schematically presented in figure 1.

The introduction of SSR Mode S and, ADS and ADS-C will provide access to a large set of aircraft-derived data of high importance for the SDPD and ATM functions through flexible (broadcast or point-to-point) modes of operation. The aircraft-derived data of interest include the unique aircraft address, state vector information, intention data etc. The processing of these aircraft-derived data is expected to improve the quality of the Air Situation Picture.

The ECAC Surveillance Strategy and the SDPD Strategy, which outline the policy within the ECAC area with respect to the Surveillance system in general and the SDPD system in particular, state that

> *The future SDPD system is required to process Surveillance data from all available Surveillance Data Sources with varying degrees of overlap so that to perform an assessment of the Air Situation Picture with an improved quality***.**

The future EATCHIP SDPD system shall be capable of providing Surveillance data to ATM and other User functions, including those currently served by ARTAS (e.g. Controller Situation Display, FPPS and Safety nets). Also, future functions, such as Medium term conflict detection, Trajectory prediction tools, Monitoring aids, Departure and arrival management functions, Meteorological Data Management, shall be supported. Therefore,

> *The future SDPD is required to provide Surveillance Data Services, adapted to the needs of the different end users, in new available surveillance airborne parameters.*

Furthermore, the availability of a very large set of data items, which can be transmitted by the Data Sources with various alternative transmission characteristics, requires

> *a function, which manages the Data Sources, to ensure that the transmission and use of data from the Data Sources is cost-effective and to avoid an overflow of overlapping and unnecessary information.*

Within ECAC, the SSR Mode-S environment will require co-ordination of Mode-S Data Sources in order to reduce RF pollution. The co-ordination includes the transmission of target information to an SSR Mode-S sensor over the ground network when necessary, for example, in the case of a missed detection, or an aircraft entering the coverage of a Mode-S radar. This surveillance co-ordination and support function may be performed in a distributed mode (i.e. through co-ordination by the Mode-S Stations themselves) or in a centralised mode:

> *The future SDPD is required to be able to perform the centralised surveillance co-ordination and support function of a Mode-S network.*

2.2 General EATM 2000+ Requirements

The expected severe increase of air traffic demand in ECAC area for the years 2000-2010 has led to assess for technical and functional solutions enabling to meet these very demanding requirements. Indeed, the required changes will concern the whole spectrum of the current air service infrastructure (aircraft, airport, surveillance equipment, ATM ground functions…) and a large variety of programmes have or will be launched. The major functional changes required for the future SDPD have been described in previous chapter.

Apart from its technical feasibility, every programme, and particularly the future SDPD, shall be evaluated against a set of general requirements, which reflect the economics and safety principles of today’s commercial aviation:

> *The solution shall allow an easy transition for changes; changes shall enhance, and at least not degrade, safety and performances; the solution shall be cost effective; the avionics requirements shall be considered in parallel; a common approach shall be favoured between ECAC countries.*

3 An ARTAS2 Solution for the Future SDPD

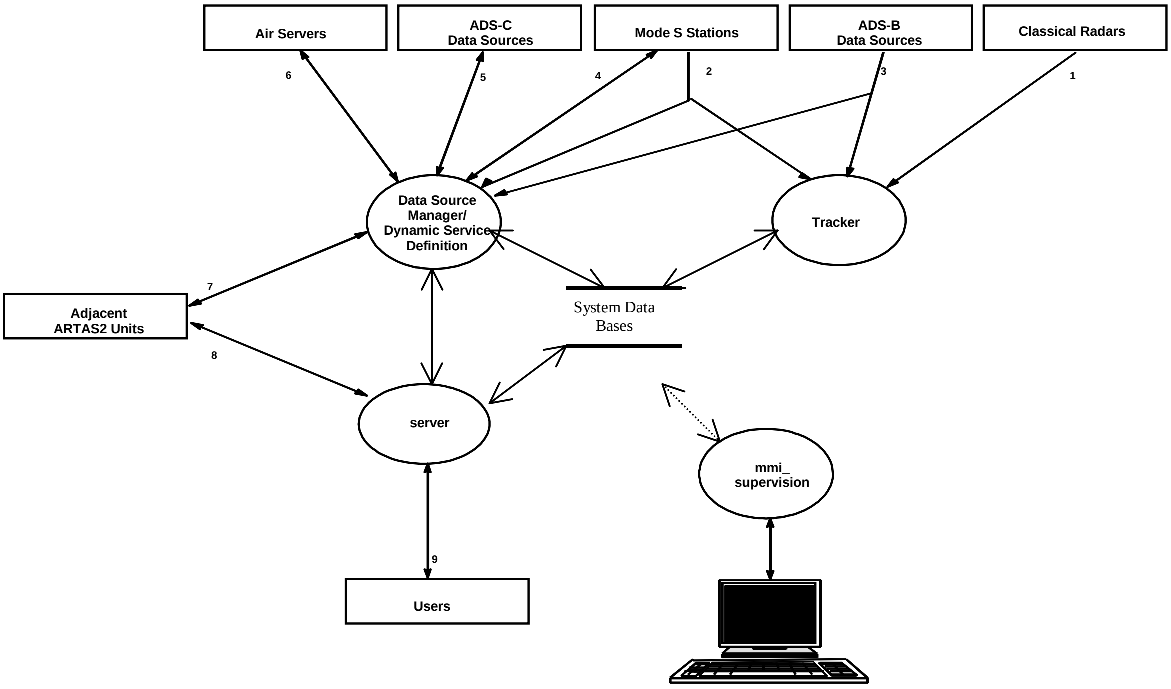
The ARTAS (ATM Radar Tracker and Server) System was developed, within the context of EATCHIP, to address all perceived Radar Data Processing System problems. In particular, the ARTAS System allows for high tracking performance, offers standardised interfaces and allows users to be served with track information according to adaptable parameters, including track data items and transmission characteristics.

Several ECAC countries have committed to operationally use the ARTAS System.
Considering the already high level of performance offered by the ARTAS System, its foreseen use by many ECAC countries and the already standardised approach it offers, an extension of the ARTAS System to cope with the future SDPD functional requirements appears to be the best solution with respect to the general EATM 2000+ ones (improvement of performance, easy transition, cost effectiveness…).

3.1 Feasibility Study

As a first step towards the implementation of an ARTAS2 System, a feasibility study, was conducted by AIRSYS ATM and NLR from November 1997 to April 1999. The aim of this feasibility study was to elaborate an ARTAS2 functional architecture (while producing the corresponding System/Segment Specification Document) and to assess the feasibility of the major new functional requirements through prototyping and subsequent evaluation.
Figure 2 shows the high level functional architecture of the ARTAS2 System, as issued from the ARTAS2 System/Segment Specification document.
One element of the study was to prototype enhancements of the ARTAS IMM tracking filter in order to evaluate the integration of the new, airborne, surveillance information. This is described in more detail in the next sections.
Another part of the study consisted in assessing which new types of services would be required by the end users following the introduction of Surveillance Data Sources –Mode S, ADS- with the capability to downlink Surveillance Aircraft Derived Data.
A new function, named "Data Source Manager", was designed, which dynamically defines the contracts with the Data Sources, as derived in response to service requests from Users or, implicitly, from the quality of surveillance data required to maintain the best Air Situation Picture (i.e. for tracking purposes). Moreover, requirements to optimise, in terms of cost and load, the allocation of contracts over all available Data Sources was also assigned to that function.

A Data Source Manager prototyping was also performed. Making use of advanced informatics technology such as Constrained Programming Language, it enabled to test the feasibility of an optimised concurrent management of Data Sources with respect to provision of new types of Surveillance Services.



ARTAS2 high level functional architecture

1 : Classical Radars Information messages (plots / local tracks, radar service messages)
2 : Elementary Surveillance or Static Enhanced Surveillance Information messages, Service messages
3 : ADS-B reports
4 : Dynamic Enhanced Surveillance Information messages (requests from ARTAS2, acknowledgements / information reports from Data Sources)
5 : ADS-C related messages (contract request from ARTAS2, acknowledgements / information reports from Data Sources)
6 : Messages exchanged with Air Servers (Requests from local ARTAS2 Unit for Aircraft Derived Data Information, acknowledgements / information reports from External Servers), only in the scope of Enhanced Surveillance Service
7, 8 : Messages exchanged with Adjacent ARTAS2 Units
9 : Requests for Services from Users, Acknowledgements / Information reports from ARTAS2

Fig. 2 ARTAS2 Architecture

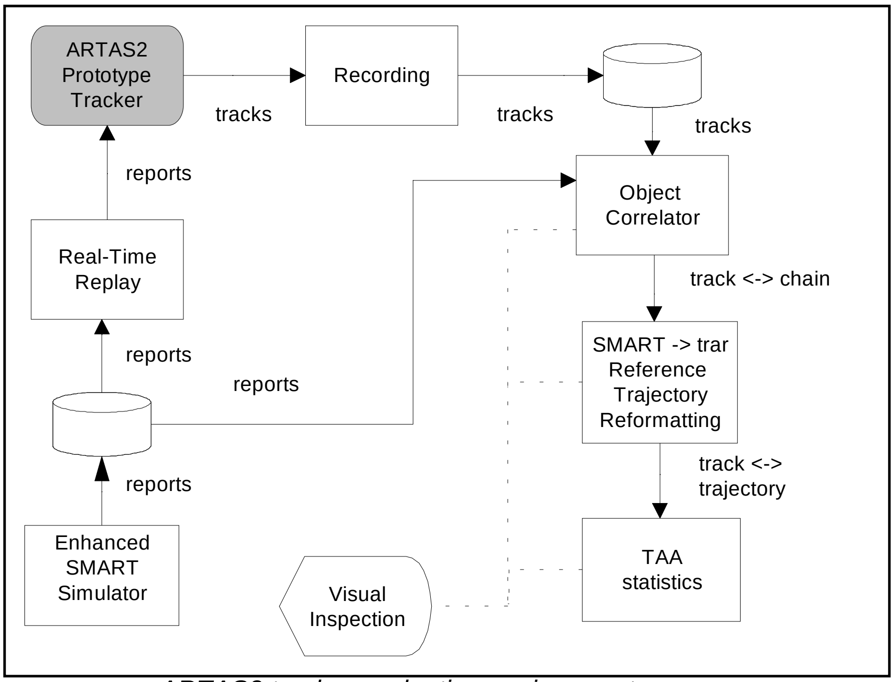
4 Tracker Prototyping

The ARTAS2 tracker prototype is based on the existing ARTAS tracker, which was extended to incorporate the processing of aircraft-derived data, such as groundspeed and altitude rate. The emphasis of the feasibility study was put on the integration of aircraft-derived data with data from a classical radar environment. This was done, not because the situation, where there is dependent surveillance only, is considered less important, but because a mixed environment is considered to pose the biggest challenge to a SDPD. Due to study constraints, onboard sensors were supposed not to deliver biased measurements. This issue is addressed in the study, described in the next section.

The integration of the aircraft-derived data is done at filter level, i.e. the filter and measurement equations were adapted to handle the aircraft-derived data, in addition to radar data. This measurement fusion solution differs from the track-fusion approach, that is used in some other architectures. Measurement fusion offers a, potentially, much better performance.

The performance evaluations were done using the environment as shown in figure 3. Target reports are generated with the Enhanced SMART simulator (ADS-B, Mode-S and PR/SSR). These reports are replayed in real time as input for the tracker prototype. The tracker output is recorded for off-line analysis. This off-line analysis consists of track-trajectory correlation (Object Correlator), generation of trajectory reference reports (SMART -> trar Reference Trajectory Reformatting) and statistical analysis of the differences between track updates and trajectory reference reports using Track Accuracy Analysis (TAA) statistics.

The performance results from the tracker prototype are promising: they show a clear performance improvement, even in the mixed surveillance environment, where the performance of the tracker is already very good without the use of aircraft-derived data.

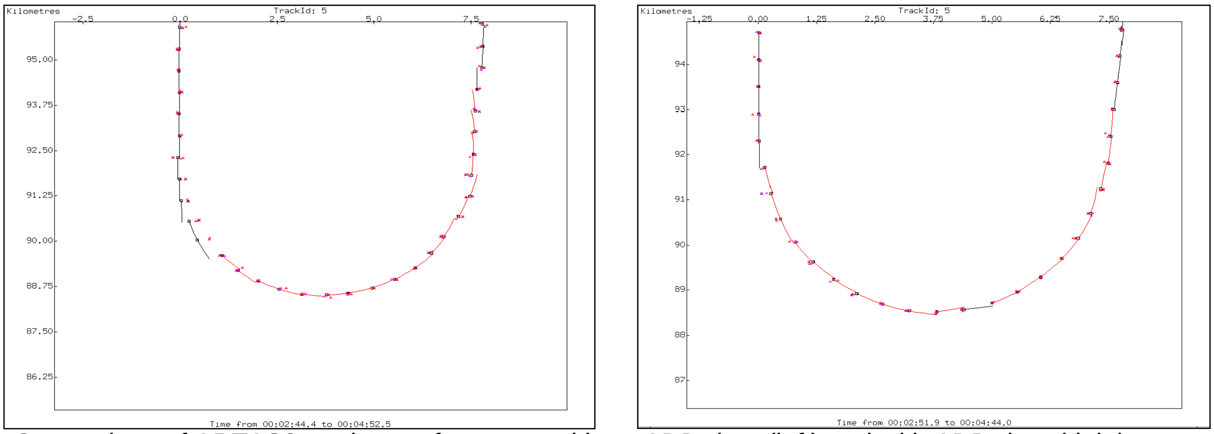


ARTAS2 tracker evaluation environment

Fig. 3 ARTAS2 evaluation environment

5 Tracker Performance Results

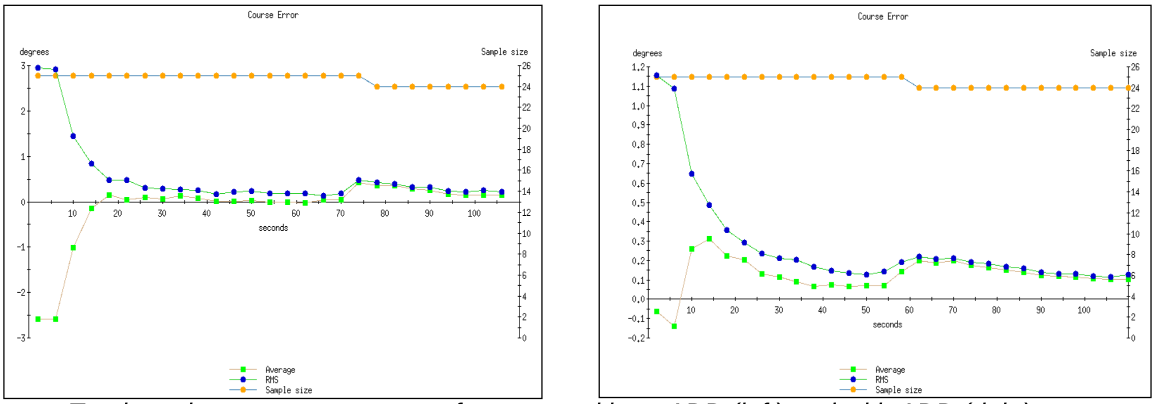
This section presents some results obtained within the above described test bed. Tests were executed with both mono-sensor and multi-sensor scenarios. The mono-sensor scenarios were used to obtain absolute performance figures, i.e. accuracy (steady state), overshoot after a manoeuvre and Mode Of Flight (MOF) detection performance. The multi-sensor scenarios were used to get an impression of the performance improvement with different sensor configurations. Figure 4 shows the performance of the ARTAS2 tracker in a turn without aircraft-derived data and with aircraft-derived data. The benefit from using aircraft-derived data is apparent.



Comparison of ARTAS2 tracker performance without ADD data (left) and with ADD data (right)

Fig. 4 ARTAS2 tracker performance in Vurus

Figure 5 shows the convergence of the track angle after a turn. The overshoot is considerably less and the converged error is a bit smaller (note the different vertical scale!). The small, temporary, increase in track angle error is an artefact of the ARTAS2 co-ordinate transformation.



Track angle error convergence after a turn without ADD (left) and with ADD (right)

Fig. 5 ARTAS2 track angle error convergence

Figures 6, 7 and 8 show the results of a multisensor scenario. In figure 6, the tracks went from uniform motion (UM) to a standard turn and, in figure 7, the tracks went from a standard turn to uniform motion (UM). The values in first row of each table indicate the peak value of the overshoot in position (across track and along track), groundspeed and course angle in the situation that the target is seen by two monopulse SSR radars. The subsequent rows indicate the percentage of improvement when one of the monopulse radars is replaced by mode-S and/or ADS-B. Figure 8, finally, shows the converged RMS error after a turn.

Trajectory 11 060X	**Across track position**	**Along track position**	**Groundspeed**	**Course angle**
2 x MSSRs (absolute figures)	137 m	38 m	3.7 m/s	15.5 deg
MSSR + Mode S (gain in %)	69%	36%	65%	63%
MSSR + ADS (gain in %)	49%	46%	78%	53%
MSSR + Mode S + ADS (gain in %)	78%	44%	78%	75%

Multisensor scenarios – peak RMS error improvement factors, UM->turn

Fig. 6 Peak RMS error, UM->turn

Trajectory 11 070X	**Across track position**	**Along track position**	**Groundspeed**	**Course angle**
2 x MSSRs (absolute figures)	67 m	32 m	3.1 m/s	9.3 deg
MSSR + Mode S (gain in %)	38%	13%	72%	73%
MSSR + ADS (gain in %)	52%	19%	77%	64%
MSSR + Mode S + ADS (gain in %)	66%	14%	71%	82%

Multisensor scenarios – peak RMS error improvement factors, turn->UM

Fig. 7 Peak RMS error, turn->UM

Trajectory 11 070X	**Across track position**	**Along track position**	**Groundspeed**	**Course angle**
2 x MSSRs (absolute figures)	33 m	20 m	0.2 m/s	0.35 deg
MSSR + Mode S (gain in %)	28%	-1%	69%	67%
MSSR + ADS (gain in %)	66%	-17%	55%	73%
MSSR + Mode S + ADS (gain in %)	69%	-4%	71%	74%

Multisensor scenarios – convergence RMS error improvement factors, turn->UM

Fig. 8 Peak RMS error, turn->UM

In figure 8, the use of ADS causes a degradation in the along track position error. This occurs, because the track is close to the monopulse SSR radar and, hence, the measurement of the monopulse radar is more accurate than the ADS position report.

6 Quality of Service Study

This study addresses the issue of onboard sensor accuracy and bias. Whereas in the classical environment, there are few sensors with well-known characteristics, in the dependent surveillance environment, there will be many onboard sensors with widely varying performance and reliability. Only limited information about the sensor is available. In order to use these onboard sensors in a reliable way, functions to estimate and monitor the quality of the onboard sensors are needed. These functions are part of the, so-called, MSEA, the Multisensor Environment Assessment of the tracker.
Prototype dynamic sensor accuracy and bias estimators have been developed and evaluation of these estimators within the ARTAS2 tracker prototype has just been started. Both functions work in real-time and adapt to abrupt changes in characteristics due to, e.g., changes in available navigation aids (RNAV, GPS). Such changes result in changes of bias and accuracy of the sensor reports.

The aim of the study is to derive representative performance requirements for the future SDPD. To that end, scenarios have been defined for a mixed surveillance environment. After completion of initial test and tuning, these scenarios will be processed by the prototype ARTAS2 tracker.

7 Conclusion

Key elements of the future SDPD have been prototyped and evaluated within a mixed surveillance environment with promising results. A number of issues affecting the ability to reliably use aircraft-derived data within SDPD systems have been raised (e.g. the lack of accurate aircraft-derived measurement time stamps, the inability to identify the onboard sensor and the limited availability of sensor characteristics data). Prototyping and evaluation activities are continued to address these issues.

8 References

[1] A Surveillance Strategy for ECAC,
Edition 1.0, November 1997

[2] Surveillance Data Processing and Distribution Strategy in the ECAC area,
Edition 1.0, December 1997